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Advancing Sustainability Through University Academic Formation – Experience with a Professional Engineering Programme.

Aisling D. O'Sullivan and David J. Painter
Consultancy for Eco-Logical Technical Solutions (CELTS)
Natural Resources Engineering
University of Canterbury

Introduction

Heightened awareness of unsustainable resource use and damaging ecosystem impacts that overshoot the carrying capacity of our biosphere are often dated from the 1972 report entitled 'The Limits of Growth', which was produced from the United Nations (UN) Conference on the Human Environment (Meadows et al.1972). Subsequently, the term 'sustainable development' was adopted in 1987 following the release of 'Our Common Future' (also referred to as 'The Brundtland Report') by the UN commission chaired by the Norwegian Prime Minister, Gro Harlem Brundtland (WCED 1987). The renowned economics professor and pioneer critic of the validity of conventional economics, Herman E. Daly, explained that sustainable growth is not possible (but that sustainable development is) since the economy is an open sub-system of the earth's ecosystem, which is finite, non-growing and materially closed (Daly and Townsend 1993). The first global summit that simultaneously addressed environmental concerns and integrated economic development was held in 1992 in Rio de Janeiro. The 'Earth Summit', as it became known, marked the international political recognition of urgency to take action (UNCED 1992) and provided 'Agenda 21' as the take-home list for national action. New Zealand was a participant at this Summit.

The over-arching message from Agenda 21 is that a holistic approach to sustainable development is critical and that inter-relationships (and interdependencies) must be recognised between people, the environment and the economy as core requirements of sustainable development. Such an interrelated approach is commonly referred to as the triple bottom line (Milne et al. 2005). In itself, Agenda 21 served as a domino initiative at the international level; it designated the period 2005-2014 the 'Decade of Education for Sustainable Development'. One particularly relevant message for this paper from the Agenda 21 report is that it states: "Education is critical for promoting sustainable development and improving the capacity of people to address environment and development issues" (Section 36.3). Therefore, it is pertinent timing to assess how we adopt this initiative in our role as educators within the engineering profession and seek ways to align our teaching to the principles and practices adopted by the New Zealand government through implementing Agenda 21 and the 2003 Sustainable Development for New Zealand Programme of Action.

It is now well recognised that human activities cause unsustainable resource use and consequent negative impacts on the environment in which they are embedded. In particular, this is recognised among personnel of international agencies, national governments and organisations and many individuals in both developed and less-developed countries. Such recognition is apparent in New Zealand at national level through legislation such as the Resource Management Act (1991) and policy statements like the Sustainable Development for New Zealand Programme of Action (2003) and the Sustainable Water Programme of Action (2006). At regional and local levels, the recognition is apparent in many of the policy statements and plans prepared under the Resource Management Act, such as the 2004 Canterbury Natural Resources Regional Plan (ECan 2006) and the 2005 Long Term Christchurch Community Plan (CCC 2006). However, it is not clear how required changes to current resource use and ensuing environmental impacts can be implemented through appropriate action in a pragmatic manner. Nor is it apparent how tertiary education, particularly engineering that is the cornerstone of technical developments, integrates sustainable thinking or ecological appreciation into an individual student's ethos (Painter and Dakers 1997, Boyle 1999, Vanderburg 1999). Without such educational instruction, how can future developments become sustainable in New Zealand? This is what we explore in this paper and lead onto proposing some methods developed here and overseas where effective integration of ecological sustainability and professional engineering formation has commenced.

Why Engineers?

Major recent investigations like the Living Planet Report (WWF 2004), the Millennium Ecosystem Assessment (MEA 2005) and the Global Ecological Footprint (Wackernagel and Silverstein 2000), suggest that responses towards reversing ecological degradation made so far are both minimal and belated. We believe that it is not primarily a lack of awareness of the problems, nor always a lack of understanding of what changes need to be made, which has led to these inadequate responses. Rather, it is a lack of urgency and will at the individual level, which translates into a lack of urgency and will at tertiary education and national political level. This belief resonates in literature specifically concerned with engineering education (Thom 1998, Boyle 1999) and is relevant to our present focus on motivation towards sustainability of students in professional engineering programmes.

Engineers are charged with making important decisions, including technical and business decisions, on projects which modify the natural environment in some form (Gillin 1992). Engineering projects, and thus engineers by profession, impact on the natural resource base supply and waste discharges generated in the environment. Those engineers whose sub-disciplines see them working closely at the ecosystem/economy boundary (mining, forest, water resources, coastal, environmental and natural resources engineers, for example), are probably more aware of the ecosystems effects of their projects. Other engineers working within the economy (civil, mechanical, electrical, chemical, and software engineers, for example) might claim to not have such direct ecosystem effects, and therefore are less directly to be concerned about the sustainability of their engineering. However, any thoughtful analysis of the sources of their resources, and the sinks for their wastes, might soon highlight direct and indirect environmental impacts of their work. Indeed, many non-engineers believe that engineers are at the forefront of implementing *un*sustainable resource use and *un*sustainable modification of natural systems (Painter and Dakers 1997, Peet and Mulder 2004). But engineers are instrumental for providing safe and reliable infrastructure needs and wants that enable civilisation to develop. Therefore, it should be logical that engineers are largely represented among the responsible guardians and managers of the environment in order to sustain the biocapacity of the planet (Gillin 1992, Elms and Wilkinson 1995, Boyle 1999, Mihelcic et al. 2003, Cruickshank 2004). This can only happen if engineers are sufficiently educated about how their impacts can affect the biocapacity of the environment in which they are working.

We propose that *all* engineers should receive some educational instruction on ecosystems in order to appreciate sustainable development in their future profession. An engineering student should graduate with the knowledge and appreciation of how sustaining natural capital through professional practice is crucial for maintaining our biotic economy (Hawken et al. 1999). An appreciation of this interdependence between ecosystems and the economy is not apparent amongst most engineering students. By extension, we support previous propositions that a sub-set of engineers should be especially educated about the 'preventive approaches' that allow them to practise engineering in a more sustainable manner (Vanderburg 1999). Others refer to this as a metadiscipline of sustainability science and engineering (Mihelcic et al. 2003), which includes a core thread of ethics, ecological sustainability and interdisciplinary learning about living systems alongside the more technical content of engineering. Similar curricula are referred to as ecological engineering (Bergen et al. 2001, Matlock et al. 2001, Odum and Odum 2003), biosystems engineering (NUID 2005), biological and agricultural engineering (Cauble et al. 2000, Krutz and Schueller 2000), bioresources engineering (Johnson 2006) and natural resources engineering (Painter and Dakers 1997, Painter 2003). We have most experience with teaching the curriculum of the professional (honours) degree in natural resources engineering at the University of Canterbury in New Zealand and so this is the focus of this paper.

Sustainability Learning in Professional Engineering Programmes in New Zealand

Accreditation Process in New Zealand

Accreditation of professional engineering university degree programmes in New Zealand is carried out by the Institution of Professional Engineers New Zealand (IPENZ). There are currently 36 four-year programmes at seven tertiary education organisations listed on the IPENZ website (www.ipenz.org.nz). These programmes are internationally recognised through the 1988 Washington Accord, an agreement among nine countries in 2006. There are also 13 three-year engineering technology programmes from six tertiary education institutes currently listed, with international recognition through the 2001 Sydney Accord, involving six countries in 2006. IPENZ recently became a provisional signatory, joining four other countries, in the Dublin Accord, which endorses two-year engineering diplomas. Current accreditation requirements specifically related to the four-year professional engineering programmes are contained in the Manual for the Accreditation of Engineering Programmes (IPENZ 2005) and the Requirements for Initial Academic Education for Professional Engineers (IPENZ 2003). This accreditation relates to the “initial academic education” (i.e. undergraduate formation); it is expected to be followed by monitored training and experience leading to membership of the Institution and ‘Chartered Professional Engineer’ status in most cases. The documents include specific references to: “sustainable engineering”, “sustainable development”, “sustainable design”, and “sustainable technology”.

Professional engineering is defined (IPENZ 2005) as “the timely, methodical, disciplined and conscientious application of scientific, technical and management skills in a socially, economically, ethically and aesthetically aware way, for the benefit of society.” Thus, there is “moral exhortation” apparent in the requirements. Graduates are expected to “understand the role of engineers and their responsibility to society by demonstrating an understanding of the *general responsibilities* of a professional engineer.” General responsibilities include “environmental responsibilities, including sustainable development and design and legislative responsibilities”. The curriculum must include “an understanding of the issues of professional responsibility, social and environmental effects, and the ethical aspects of engineering practice.” There should also be “an understanding of sustainable technology and development” and this material “should be integrated throughout the curriculum where students are asked to consider the impacts of design upon New Zealand society and upon other nations and cultures. A systems approach should be used, including interdisciplinary teams, to teach sustainable engineering concepts” (IPENZ 2003, 2005).

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Evidence of Sustainability Learning in Accredited Programmes

"Sustainable management of resources is a vital dimension in the "clean-green" economy and the quality of life of the various communities in New Zealand. Within the University of Auckland, research and teaching in the field of sustainable management of resources is of very extensive importance - approximately twelve departments across five faculties have research and teaching interests in this area." (www.tamaki.auckland.ac.nz) More specifically, the Undergraduate Handbook of the Faculty of Engineering at the University of Auckland lists one course (ENGGEN 403) entitled "Professional and Sustainability Issues" which is a core (required) course in all nine accredited programmes. It contains "Issues of particular relevance to the engineering profession including those relating to the law, ethics, culture and sustainability." This demonstrates that students in all engineering degrees at the University of Auckland receive some instruction in sustainability concepts before they graduate.

The Charter of the University of Canterbury states that it "will pursue equity and environmental sustainability in all of the University's activities". The core reasons for continued existence of universities include developing understanding and critical thinking skills in the next generation of students in all disciplines. It might be reasonably inferred that environmental sustainability instruction is therefore provided in every programme. This is not the case. The University of Canterbury's 'Sustainability' webpage has made excellent progress in attempting to identify where sustainability concepts are included in courses throughout the University (www.sustain.canterbury.ac.nz/courses) but acknowledges that little is known about the extent or direction of teaching environmental sustainability in these courses (Pers. comm. Dr Kate Hewson, University of Canterbury Advocate for Sustainability).

No courses in the accredited engineering programmes at the University of Canterbury refer to 'sustainability' in course titles or prescriptions. However, in the natural resources engineering programme with which we are most familiar, at least seven courses are relevant. "Environmental Quality and Ecosystems" (ENNR 203) is a required course in the second year of the BE(Hons) in Civil Engineering, the BE(Hons) in Forest Engineering and the BE(Hons) in Natural Resources Engineering. It contains "Introduction to ecology, hydrology and microbiology; society and the environment; Resource Management Act; mass balances; water quality parameters." The other six (five required) relevant courses are in the BE(Hons) Natural Resources Engineering degree only. They are outlined as follows. "Natural Resources Engineering 2" (ENNR 304) contains "Case studies in Natural Resources Engineering; legal and cultural constraints, applied ecology, environmental impact assessment; use of spatial data and analysis systems; introductory bioengineering." "Ecological Engineering 1" (ENNR 305) contains "Natural and human systems; system self design; ecosystem processes; concepts and principles of ecological engineering." "Ecological Engineering 2" (ENNR 405) contains "Design and practices of ecological engineering, technologies for the treatment of wastewaters, rehabilitation of contaminated lands, soil bioengineering (erosion control) and economics", while "Natural and Human Systems" (ENNR 460) contains "System theory and analysis; Open systems; ecological systems; human systems and examples of system behaviour in the biosphere." The fifth relevant course is an elective in the final year. "Energy Resources Engineering" (ENNR 423) contains "Principles, applications and design of energy production using natural resources, especially wind, solar, hydro, biomass and geothermal; Energy conservation, demand, and policy; Energy and global environmental issues; Design of energy use systems." All final year natural resources engineering students embark on a required full year (0.2 EFTS) project that "provides an opportunity for students to demonstrate their abilities in the detailed application and integration of engineering and related skills to a particular topic in Natural Resources Engineering, including communicating the implications of engineering projects in relation to the principles of the Treaty of Waitangi." According to the engineering curriculum, it seems that natural resources engineering is preparing students with the integrated ecological, economic and social skills for application to their technical problem solving skills in line with future sustainable developments. The important question of whether this motivates these students to incorporate sustainable thinking and ecological appreciation into their individual ethos remains unmeasured, which we address below.

Sustainability Learning in Professional Engineering Programmes Overseas

We have not conducted extensive research on overseas experience with motivating engineering students towards environmental sustainability. From our own professional contacts, experience (albeit limited) and interaction with visiting academics internationally, most investigations indicate that situations in Australia, North America, Ireland and the UK are similar to the New Zealand situation. Programmes offered in cooperation under engineering and ecological or biological auspices appear to present the most explicit recognition of sustainability issues but we have no measure of how students in those interdisciplinary programmes are motivated towards environmental sustainability. Nonetheless, methods developed overseas to effectively integrate ecological sustainability and professional engineering are reported in Europe (Glavic 2006), including at the University of Cambridge (Cruickshank 2004), in the USA (Matlock et al. 2001, Mihelcic 2003, Odum and Odum 2003,) and in Australia (SEEK 2005). We will endeavour to explore the results of these efforts in the near future.

The Importance of Motivation and Barriers to Integrating Sustainability into Engineering Curricula

Sustainability Aotearoa New Zealand note in their 'sustainability stocktake' earlier this year (Peet et al. 2006) that sustainability is a *moral* issue. Others documented the same in relation to engineering students (Painter and Dakers 1997), while Mihelcic et al. (2003) report that the challenge for engineering programmes is to demonstrate to students concerned with sustainability that engineering has social value and relevance and that they can solve environmental and societal problems - something that resonates with women in particular. While the predominant focus of engineering is on technical design and problem-solving, it does not seem to attract a large proportion of technically able students whose primary focus is on solving environmental and societal problems. This in itself leads to a lack of diversity in the engineering profession, which is a well documented problem (Cauble et al. 2000).

Fritjof Capra (Capra 2006) pointed out that "the concept of sustainability is alien to most people, and many don't understand it. I found it confusing, and I ended up thinking that it was because it is a moral exhortation to create as many opportunities for future generations as possible, yet it is an exhortation that doesn't actually tell you *how* to do it. What we need instead is an *operational* definition. The key to this is that we can use ecosystems as models. They are adaptive and sustainable, they support life, they recycle, they are solar powered." By teaching the concept of environmental sustainability through models such as dynamic ecosystems, students can better appreciate the components, relationships and thus relevance of the systems they are learning about. This also leads to more realistic engagement with environmental sustainability concepts and can hopefully serve as a driver for progress towards sustainable living and healthy ecosystems. However, the understanding and experience of how to engineer with due consideration for sustaining the biocapacity of the planet is not always available to, or truly valued amongst, most engineering academics (Boyle 1999, Bergen et al. 2001, Peet and Mulder 2004). Additionally, there is a dichotomy of beliefs regarding technology developments and ecological sustainability. Some believe that technology will develop fast enough to compensate for the rate at which biophysical resources are spent while others believe that the planet's capacity to absorb society's wastes and provide raw materials and energy is limited (Costanza 1989, Kangas 2004). Perhaps this divergence in beliefs explains why most engineering students do not receive ecological sustainability instruction or motivation in their professional engineering degree programmes.

As Capra points out, a "moral exhortation" about whether engineers 'should' favour sustainable solutions to technical problems is not on the same level of immediacy or priority as the '*how'* to achieve the technical result. This "moral exhortation" does not currently feature with high relative immediacy or priority for academics among the many drivers of curriculum design, course content and learning activity (Painter and Dakers 1997, Thom 1998, Boyle 1999, Vanderburg 1999, Peet and Mulder 2004). On the contrary, in the current academic professional engineering culture, "moral exhortations" and related sustainability concerns among academics are typically regarded as superfluous in a technical curriculum. Boyle (1999) identified five barriers in New Zealand to modifying tertiary curricula towards enabling sustainability and 'cleaner production' concepts to be taught. These included: (1) without specific training in this field, most academics cannot relate to sustainability concepts; (2) material that must be covered in curricula is already excessive; (3) academics are not given sufficient preparation time to modify courses; (4) research is often prioritised over teaching (and it is often by research that academics are measured for career promotion); and (5) training to mitigate (1) is not prioritised by universities or academics themselves.

Comments provided in Capra's statement apply in particular ways to motivation of professional engineering students in New Zealand towards sustainability. Sustainability is an alien and not well understood concept. Besides the concept of 'sustainability' itself being misused by various professions in their marketing practices (e.g. by economists, accountants, mineral extractors), engineering students are not well versed on how the environment works in order to practise within its biocapacity reserves. Such students, by nature, are not always focussed on or motivated towards understanding how ecosystems operate. Should we therefore be aiming to motivate and educate our future engineers about how ecosystems function and how to "design sustainable (eco)systems that effectively integrate human society with its natural environment for the benefit of both" (Odum and Odum 2003), in order to ensure that future engineering *is* practised in a sustainable way? We believe this to be the case, at least for a sub-set of students who are inherently motivated towards integrating engineering and environmental sustainability.

Professional engineering students, by personality and predilection, are technical thinkers and problem solvers with a focus on 'how' to achieve a technical goal, prescribed by an employer or a client. Many engineers think in a linear manner without believing in the need to understand the whole system or ecological and socio-economic implications of their work. Even studying processes and examples of moral choosing, in course content on ethics for example, is (and arguably should be) itself, a morally neutral activity. We have found many engineering students struggle with these issues and are more content to work on a calculation-based exercise where the answer can be well-defined and non-debateable. Is it therefore more effective to allow students to develop their own moral standing associated with their future engineering practice by showing them the ecological impacts of their activities and how ecosystems respond to such impacts? This is an approach we have adopted in one course common at the second year for natural resources, civil and forest engineers at the University of Canterbury. The name of this course has also undergone a recent change from Environmental Engineering 1 to Environmental Quality and Ecosystems (from 2007) to reflect the change in content and teaching approach. In the natural resources engineering degree specifically, we adopt the approach of engineering in partnership with nature (as opposed to controlling nature's forces) throughout all professional years of the degree. We have found that this degree seems to attract students who are inherently concerned with environmental sustainability and motivated by engineering solutions towards working in conjunction with ecosystems. In this degree, we also focus on the 'preventive' approach of engineering in partnership with the biophysical environment and so it contains substantial instruction on understanding and modelling the dynamics of ecosystems in response to human-induced change.

Experience with Motivating Sustainability in Natural Resources Engineering

Genesis

The BE(Agricultural) began in 1967 as a University of Canterbury programme jointly taught with Lincoln University. It was renamed BE(Natural Resources) in 1990 and became BE(Hons) in Natural Resources Engineering when all the University of Canterbury engineering bachelors degrees were so designated in 1995. There was also thriving postgraduate activity in Natural Resources Engineering at Lincoln University, with ME(NatRes) and PhD in Natural Resources Engineering awarded. The number of students enrolling in the undergraduate natural resources engineering degree has markedly increased since 2002, perhaps partly as a result of more awareness in primary and secondary schools about the importance of environmental sustainability. Concomitant demand for postgraduate research in this area is evident. While this degree is certainly not the only professional engineering programme to include environmental sustainability awareness in its curriculum, it does provide an underlying core, in all its professional years, that integrates ecological sustainability with technical problem-solving and design. It is similar in instruction to the metadiscipline of sustainability science and engineering reported elsewhere (Bergen et al. 2001, Mihelcic et al. 2003) and aligns with the direction of ecological engineering education and practice, which is well documented (Bergen et al. 2001, Matlock et al. 2001, Odum and Odum 2003, Kangas 2004). Our experiences with teaching primarily into this degree programme are documented as an example of possible ways to integrate both understanding of ecological sustainability, and motivation towards it, into the core curriculum of professional engineering in New Zealand for contributing to future sustainable development.

Assignments that Relate to Real-World Problem-Solving in Partnership with Nature

In the second year (currently co-taught with civil engineering) of the natural resources engineering degree in 2006, students were assigned the task of performing a hypothetical ecohydrology site assessment as part of an AEE (Assessment of Environmental Effects) for a proposed large residential development north of Christchurch. The scenario given was contextual, current and required systems thinking. Its purpose was for students to interrelate material they learnt across the course (ENNR 203), particularly identifying the interdependence of ecosystems, hydrology (water supply and quality) and economic developments. Subtle indications that the land was previously contaminated and the nearby lake was a protected wetland were provided, so that students could think logically about whether their assessment should support or not support the proposed development and what considerations must be recognised. Many students struggled with this assignment since it was (a) not calculation-based and (b) required quite a bit of *independent* thinking and logic. However, some of the 178 students excelled at this task and we believe that these students are those that can lead engineers into future sustainable development. This task demonstrated that many students find it difficult to integrate systems thinking and sustainable concepts in their engineering degree and even consider such course content peripheral to their learning.

In the third year, students specific to the natural resources engineering degree are given the task of calculating their net household ecological footprint over a period of ten weeks in a course entitled

Ecological Engineering 1 (ENNR 305). They are provided with a complex spreadsheet which contains (along with guidelines) many variables from which to assess their impacts. These include a calculation of their impact from travel, food consumption, household construction and energy use, amongst other parameters. Because of the substantial duration of this task and the requirement to physically calculate their own footprint, students are empowered to take ownership for their footprint and the results become personalised. This exercise has proven a powerful tool for educating this sub-set of engineering students about ecological sustainability concepts and how their lifestyles can impact on the biocapacity of the earth. It is meaningful to them since it is a real-world scenario that they can engage with and so it becomes effective learning with a concurrent appreciation of maintaining New Zealand's natural capital.

In the fourth year, the same sub-set of natural resources engineering students become more engaged with ecological sustainability and engineering through their year-long project course (ENNR 429) aligned with industry, local and regional councils and consultancies. All projects are real-world problem-solving exercises integrated into the local community in some form. This model has proven an effective way for students to take responsibility for delivering work on time and the opportunity to implement what they have learnt throughout their four-year degree. Recent projects have included; an energy audit for a local primary school with recommendations towards energy efficacy; quantification of (previously unknown) stormwater contaminants into the University campus waterways and proposing ecologically integrated sustainable design solutions for mitigating the ecological impacts; developing a drain restoration decision calculator for local councils in determining best management practice for maintaining drainage function and weed management and; soil conservation and nutrient retention solutions in degraded soils by using waste amendments. All projects have a core objective – to provide effective solutions to the prescribed problem by integrating ecological, economic and societal considerations in their technical challenge.

Some other courses in this degree programme also provide problem-solving exercises that require an integration of ecological sustainability and the goal of developing solutions in partnership with ecosystems. For example, in Ecological Engineering 2 (ENNR 405), students were assigned the task of converting anthropogenic waste streams into natural capital commodities. This involved writing an engineering report on the technical design and project feasibility for treating a specific (their choice) waste stream in the New Zealand context. Students researched different waste streams over a period of eight weeks and were supported in locating appropriate literature and contacting relevant stakeholders. Some excellent solutions were proposed in their final reports that integrated triple bottom line considerations and ecological economics in the New Zealand context. The goal of this assignment was to empower students to think creatively in pursuing alternative yet realistic and cost-effective methods for waste reuse and so aligned well with the principles of using ecology to steer technology for sustainable development. Boyle (1999) reported a related approach taken in engineering curricula at the University of Auckland.

What is Needed: How to Make Progress

The initiative taken by IPENZ in 2005 in providing practical guidelines for sustainability and engineering in New Zealand may have been due to the acceptance by the profession, in general, that sustainability has major implications for society and engineers. Engineers are involved in all aspects of resource use and, society's resource use (energy and materials) needs to decrease by 10 to 15-fold in order to achieve sustainability (Boyle et al. 2005). Authors of this IPENZ report indicate that such a magnitude in resource use efficiency and concurrent reduction can occur through sustainable technology designs led by engineers. Their overall message was that all engineers need to recognise this professional responsibility and start leading this field if sustainability is to be achieved since their role is pivotal. We advocate that engineers can better achieve this through adequate instruction and motivation that integrates environmental sustainability and technical rigour in their professional degree programme.

Despite achieving success with integrating environmental sustainability into some of the engineering curricula nationally, there is immense scope for improvement in the tertiary education sector. The framework presented by Vanderburg (1999), that evaluated how well (or not) such integration was implemented, is a commendable model that could be adopted in New Zealand. His work highlighted a vast potential for preventive approaches that could be developed to make engineering practice more sustainable through educating engineering students about using ecology to drive technology. Endorsement by IPENZ, and an IPENZ-led investigation evaluating where and how engineering students are taught and motivated about environmental sustainability, would be welcome. By measuring such integration, a better platform is provided on which to modify engineering curricula towards future environmental sustainability. With recent alarming conclusions on the state of our planet, coupled with the commencement of the Decade of Education for Sustainability, it is apt timing to review where sustainability *is* taught in our engineering curricula as expected by the IPENZ accreditation process. Subsequently, guidelines on what is required to deliver such expectations, is warranted. Mihelcic et al. (2003) provide an excellent framework for a new metadiscipline of sustainability science and engineering that aligns engineering students with environmental sustainability. The key success indicators with such frameworks are that integrated technological and environmental awareness requires elevating in priority and a sufficient and diverse pool of human talent must be attracted to the engineering discipline, both as students and as academics.

Conclusions

Major international assessments have concluded that resource depletion is rampant and society has overshot its ecological waste assimilation capacity. Education of future generations charged with reversing these trends is essential for environmental sustainability to happen. Since engineers impact on biophysical resource supplies and ensuing wastes, they are critical players for ensuring that ecosystems can support current and future civilisations. It will be necessary to motivate and educate student engineers about the importance of understanding and wisely using ecosystem goods and services, alongside technical material, to ensure survival of the interdependent biotic and fiscal economies. Professional engineers in New Zealand have recently provided guidelines on engineering and sustainability practice but there is limited instruction of integrated environmental sustainability and technical engineering in tertiary education. The Natural Resources Engineering degree offers some triple-bottom line instruction in its degree programme, which aligns well with sustainable development. More such integrated instruction is warranted across engineering curricula. Perhaps using ecosystems as dynamic models, with real-world applications, will provide effective instruction. The barriers to adopting environmental sustainability motivation into engineering curricula must be addressed and overcome. An evaluation of where and how environmental sustainability principles are motivating and taught to engineering students would provide a good pathway towards attaining environmental sustainability in New Zealand's future development.

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